THE ROLE AND USE OF FIRE IN THE SEMIDESERT GRASS-SHRUB TYPE

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RESEARCH SUMMARY

Historical evidence indicates that fires were present in the semidesert grass-shrub type in southeastern Arizona, but there is less supportive evidence for southern New Mexico and southwestern Texas. The change from grass to brush during the past 80 years was due to a combination of factors related to the intensification of grazing. These factors include: reduction of grass fuel, increased rodent activity, increased erosion that helps cover and irrigate mesquite seed, increased seed dispersal by livestock, increased seed source as more trees came to maturity, and reduction of the competing stands of perennial grasses.

Except for black grama, most grasses in the semidesert grass-shrub type recover from fire in 1 to 3 years. Black grama may take 3 to 8 years to recover, for droughts slow the rate of recovery. If grazing, fire, and droughts are all suppressing black grama simultaneously, it may never fully recover. Drought alone can permanently damage black grama, for the severe drought of 1951 to 1956 on the Jornada Experiment Station, without grazing, reduced black grama on deep sandy and low hummocky sites so severely that it will never recover in our lifetime (Herbel and others 1972). Forbs are not very abundant, but most seem to be favored by fire.

During dry seasons that follow 1 or 2 years of above-average summer precipitation, fire can be used to control burroweed, cactus species, broom snakeweed, creosotebush, and young mesquite plants. False-mesquite, velvet-pod mimosa, Wright baccharis, and fourwing saltbush recover quickly after burning. Wheeler sotol and barrel cactus are severely harmed by fire.

Natural fire frequency was approximated to be 10 years for southeastern Arizona. In southern New Mexico and southwestern Texas, it was probably less than every 10 years, for there is no written record of fire in southern New Mexico (Buffington and Herbel 1965).

Although fire prescriptions have not been developed for the southern desert grasslands, some general guidelines are recommended where fine fuel exceeds 600 lb/acre (674 kg/ha). These *guidelines* should be treated as such and used in conjunction with the management implications. Generally, where there are medium or heavy infestations of brush, there is not enough fine fuel to carry a fire. Research needs are mentioned in the state-of-the-art section.

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INTRODUCTION

Grasslands in the semidesert grass-shrub type have gradually given way to higher and higher densities of shrubs during the past 75 years (fig. 1), but the mechanisms by which the invasion has taken place are not well understood (Buffington and Herbel 1965; Martin 1975). The historical role of fire is especially perplexing because fires that kill shrubs usually kill grasses too (Martin 1975). Buffington and Herbel (1965) were also skeptical about the role of fire in desert grasslands and did not consider fire as a factor in the maintenance of brush-free range in southern New Mexico. However, Thornber (1907, 1909), Griffiths (1910), Wooton (1916), Leopold (1924), and Humphrey (1958) were convinced that fire controlled shrubs in those portions of the semidesert grass-shrub type that had sufficient fine fuel. "That such fires burning over the mesas and foot-hills have not been uncommon in times past may be judged by the fact that in many places abundant remains of charred stumps of at least 10 years duration are frequently met with" (Thornber 1910). Wooton (1916) commented on fires severe enough to kill plants 10 to 12 ft (3.0 to 3.7 m) high.

Despite the skepticism about fire in controlling shrubs in desert grasslands, climate has not changed enough to account for the rapid increase of shrubs (Gardner 1951; Paulsen 1956; Humphrey 1958; Buffington and Herbel 1965). Moreover, once velvet mesquite (*Prosopis glandulosa* var. *velutina*) or honey mesquite (*P. glandulosa* var. *glandulosa*) seed trees were present, mesquite seedlings increased in Arizona and New Mexico whether pastures were protected or grazed (Griffiths 1910; Wooton 1916; Leopold 1924; Glendening 1952; Buffington and Herbel 1965). This leaves the distinct possibility that occasional fires, in combination with drought, competition, rodents, and lagomorphs played a significant role in controlling shrubs in the semidesert grass-shrub type (Griffiths 1910; Wooton 1916; Leopold 1924; Branscomb 1956; Humphrey 1958; Bock and others 1976), except on black grama uplands (Buffington and Herbel 1965).

DISTRIBUTION, CLIMATE, SOILS, AND VEGETATION

Distribution

Semidesert grass-shrub vegetation occurs in broad basins, slightly sloping drainages, and lower slopes of the southern Rocky Mountains in southeastern Arizona, southern New Mexico, and southwestern Texas (fig. 2) (Humphrey 1958; Martin 1975; Bunting 1978). The relatively flat terrain is interrupted by mountain ranges that rise abruptly to elevations of 8,239 to 10,713 ft (2 512 to 3 266 m) (Humphrey 1958; Martin 1975; Bunting 1978). Approximately 44 million acres (17 813 765 ha) occur in the United States, but the center of the semidesert grass-shrub type lies in Mexico (Clements 1920). Elevation of this vegetative type usually ranges from 3,000 to 4,500 ft (915 to 1 372 m) in Arizona and New Mexico (Martin and Cable 1974), but occurs as high as 5,707 ft (1 740 m) in southwestern Texas (Bunting 1978). Below the semidesert shrub-grassland lies the Chihuahuan desert and above it the vegetation gives way to chaparral, pinyon-juniper, oak woodland, or occasionally to grassland (Martin 1975).

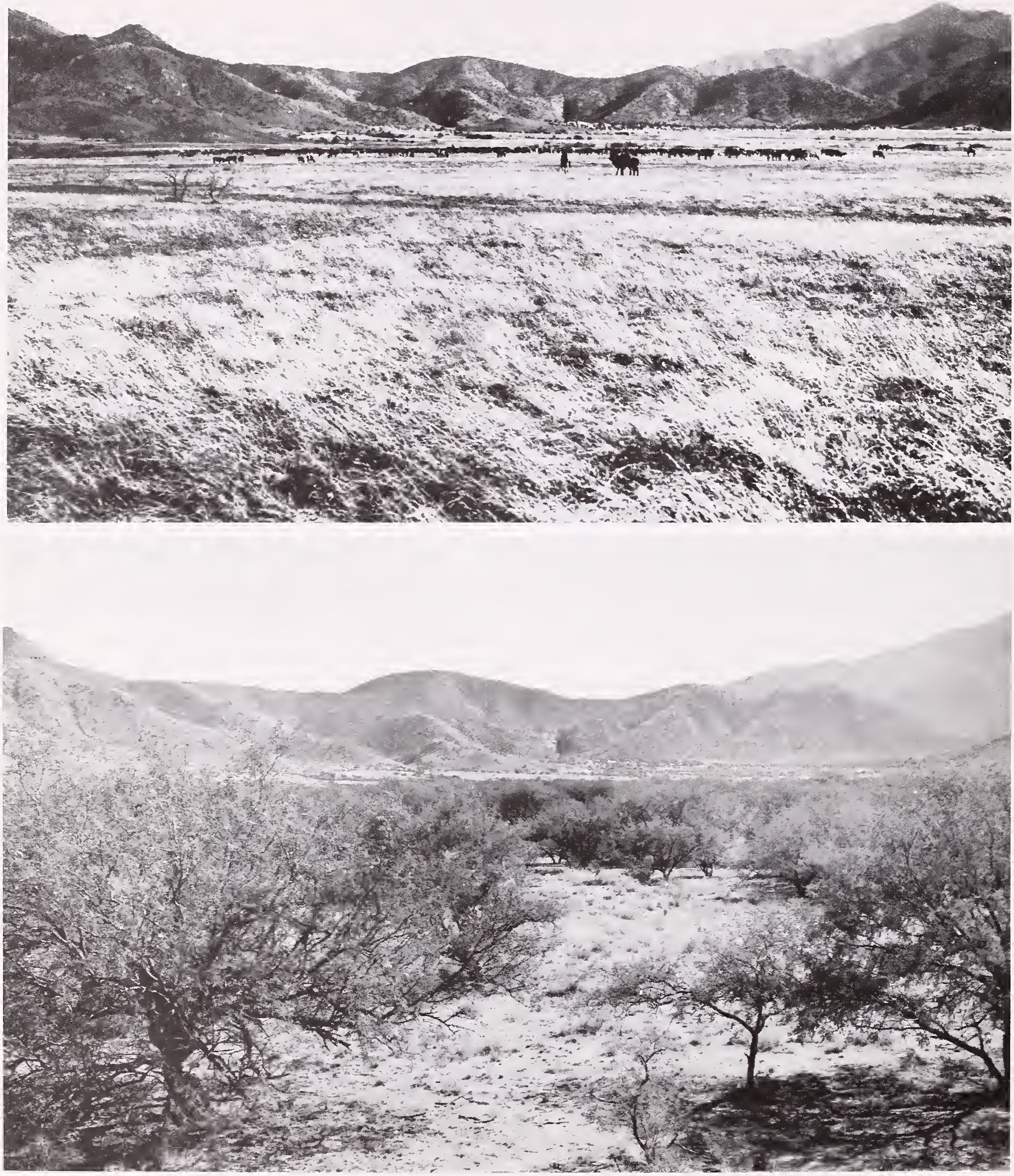

Figure 1.--A. Open grass-covered area on the Santa Rita Experimental Range in 1903. There are very few widely scattered velvet mesquite trees. B. Same area as 1A in 1941 with a well developed stand of velvet mesquite.

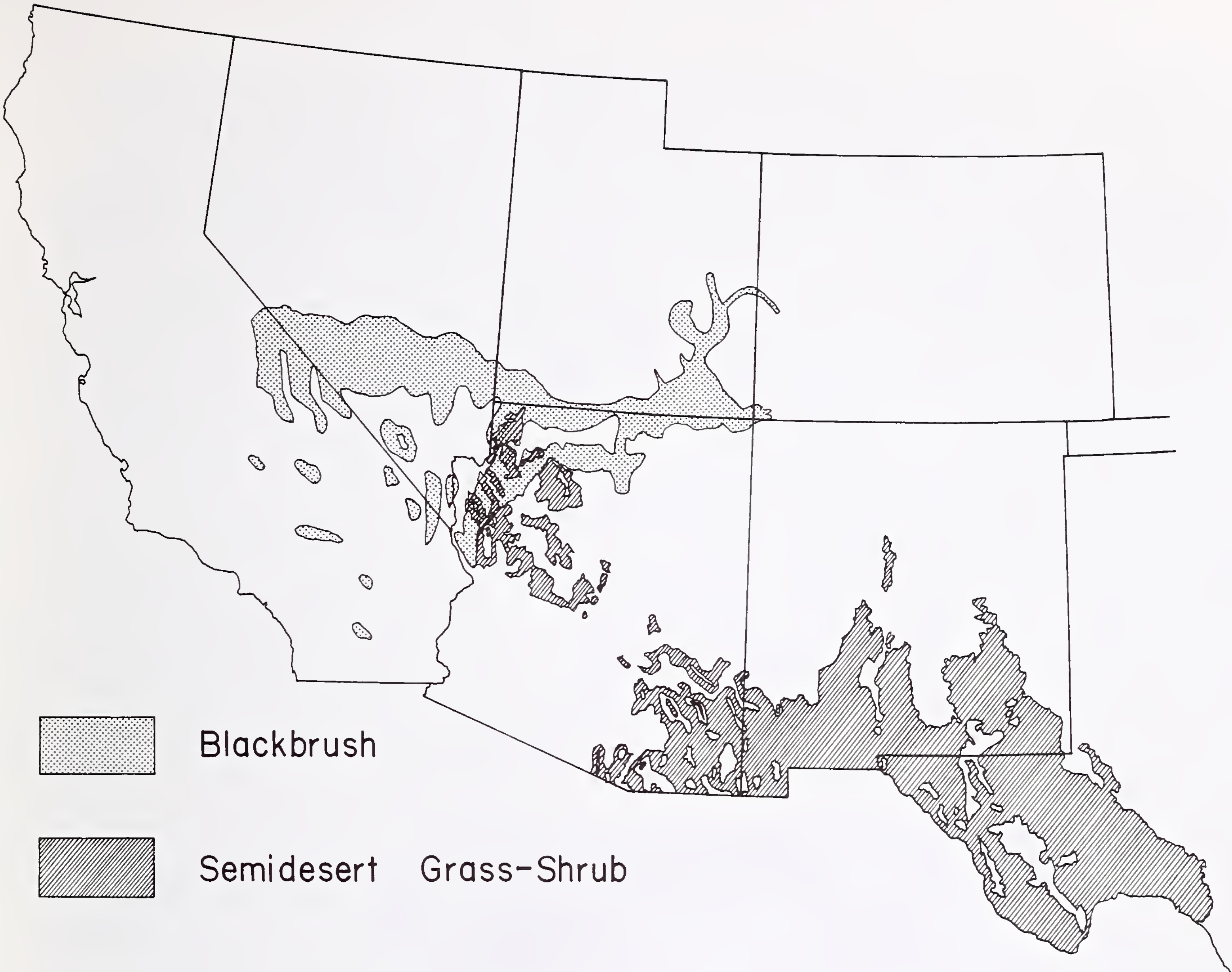

Figure 2.--Distribution of semidesert grass-shrub vegetation (after Küchler 1964) and blackbrush vegetation (after Bowns and West 1976).

Climate

Average annual precipitation ranges from 8 inches (20 cm) at the western edge of Tucson to 20 inches (51 cm) on the lower slopes of mountain ranges in southeastern Arizona and southwestern Texas (Martin 1975). In south-central New Mexico, average annual rainfall on the Jornada Experimental Range is 9.1 inches (23 cm). Throughout the semidesert grass-shrub region, over 50 percent of the annual rainfall occurs between July 1 and September 30 (Hinckley 1944; Buffington and Herbel 1965; Cable 1972).

Soils

Soils vary widely from sandy or gravelly loams to clays in both the surface and subsoil (Buffington and Herbel 1965; Cable 1972). They have developed primarily in alluvium from the adjacent igneous and limestone mountains, are characteristically immature, light colored, and low in organic matter (Bunting 1978). Light precipitation and high evaporation often result in an accumulation of salts in and below the soil in basins. Thus, concentrations of $CaCO_4.2H_2O$ (gypsum) and $CaCO_3$ (lime) occur in many soils throughout the region (Carter and Cory 1930).

Mesa and upland soils of the black grama community are compacted sands, shallow, and usually are 12 inches (30 cm) or less in depth. Frequently they are underlain by caliche (Nelson 1934; Martin 1975). Mixed grama (*Bouteloua* sp.) occurs on a wide variety of soils (Martin 1975), and mesquite grassland occurs mainly on sandy soils (Buffington and Herbel 1965). Creosotebush (*Larrea tridentata*) grows best on limestone-derived alluvial fans (Fosberg 1940) and is absent on soils having gypsum in the profile (Waterfall 1946; Buffington and Herbel 1965). Tarbush (*Flourensia cernua*) also grows on limestone-derived soils but predominates on deep well-drained soils (Buffington and Herbel 1965). Clay soils and fine silts, generally in swales and basins, are deep to moderately deep, poorly drained, calcareous, and contain appreciable quantities of readily soluble salts. They usually support tobosagrass (*Hilaria mutica*) and/or one of the sacaton species (*Sporobolus airoides, S. wrightii*) (Buffington and Herbel 1965; Bock and Bock 1978).

Vegetation

Major vegetational communities include the black grama uplands (fig. 3) of New Mexico and west Texas, the flood plains of tobosagrass (fig. 4), sacaton (*Sporobolus wrightii*) (fig. 5), or alkali sacaton (*S. airoides*) that occur along water courses, mixed grama (*B. gracilis, B. hirsuta, B. chondrosioides*) grasslands, mesquite-infested grasslands, the widespread creosotebush stands, and the tarbush, whitethorn (*Acacia constricta*), and creosotebush areas of adjoining and included portions of the Chihuahuan desert (Martin 1975).

Figure 3.--Black grama upland in southern New Mexico. Associated plants are mesa drop-seed, broom snakeweed, and soapweed. (Science and Education Administration photo)

Figure 4.--Tobosagrass flood plain that is typical of southern Arizona, New Mexico, and southwestern Texas. Soils are usually nonsaline. (Science and Education Administration photo)

Figure 5.--Sacaton grassland in southeastern Arizona. It is typical of saline flood plains.

Black grama and tobosagrass are the most common grasses in the semidesert shrub-grassland (Paulsen and Ares 1962). A rothrock grama (*Bouteloua rothrockii*) community is abundant in Arizona and a curly mesquite (*Hilaria belangeri*) community is scattered throughout the desert grassland on well-drained clay soils (Shantz and Zon 1924; Humphrey 1953). Other species in Arizona include annual needle grama (*B. aristidoides*), annual sixweeks threeawn (*Artistida adscenionis*), tall threeawns (*A. hamulosa* and *A. ternipes*), Santa Rita threeawn (*A. glabrata*), bush muhly (*Muhlenbergia porteri*), Arizona cottontop (*Trichachne californica*), tanglehead (*Heteropogon contortus*), hairy grama (*B. hirsuta*), sideoats grama (*B. curtipendula*), and plains lovegrass (*Eragrostis intermedia*). Principal plant species in New Mexico on well-drained sites include black grama, mesa dropseed (*Sporobolus flexuosus*), threeawns (*Aristida* sp.), and fluffgrass (*Erioneuron pulchellum*). Low-lying areas contain tobosagrass and burrograss (*Scleropogon brevifolius*) (Buffington and Herbel 1965). In Texas, blue grama (*B. gracilis*), sideoats grama (*B. curtipendula*), vine-mesquite (*Panicum obtusum*) warnock grama (*B. warnockii*), bush muhly, dropseed (*Sporobolus* sp.), hairy tridens (*Erioneuron pilosum*), and Wooton threeawn (*Aristida pansa*) may be added to the predominant stands of black grama, alkali sacaton, and tobosagrass (Bunting 1978). Lehmann lovegrass (*Eragrostis lehmanniana*) and Boer lovegrass (*Eragrostis chloromelas*) are the most commonly seeded grasses in the semidesert type (Martin 1975). Forbs are not very prevalent (Bunting 1978).

Common shrubs include mesquite, creosotebush, tarbush, fourwing saltbush (*Atriplex canescens*), soapweed (*Yucca elata*), and broom snakeweed (*Xanthocephalum sarothrae*) (Buffington and Herbel 1965; Martin 1975). Burroweed (*Aplopappus tenuisectus*) is prevalent in southern Arizona and southwestern New Mexico and some acacias (*Acacia* sp.) may be found throughout the entire region (Martin 1975). Cane cholla (*Opuntia spinosior*), jumping cholla (*O. fulgida*), and Englemann's pricklypear (*O. engelmannii*) are common cactus species (Cable 1972).

Herbage Yields

Herbage yields are quite variable. Martin (1966) found that herbage yields ranged from 5 to 250 lb/acre (5.6 to 281 kg/ha) on a mesquite-infested range that received 10 to 12 inches (25 to 30 cm) of precipitation annually. In an area of higher annual rainfall (16 inches [41 cm]), yields ranged from 300 to 1,200 lb/acre (337 to 1 348 kg/ha) under a scattered stand of mesquite. In another case on the Santa Rita Experimental Range where precipitation averaged from 7.4 inches (19 cm) in the driest pasture to 10.8 inches (27 cm) in the wettest pasture, yields ranged from 17 to 498 lb/acre (19 to 560 kg/ha) (Martin 1975). On the Jornada Experimental Range where precipitation averages 9.1 inches (23 cm) annually, Herbel (cited by Martin 1975) reported yields as high as 800 lb/acre (899 kg/ha) on black grama upland sites and 3,500 lb/acre (3 933 kg/ha) on tobosa-alkali sacaton flood plains.

POSSIBLE ROLE OF FIRE IN SEMIDESERT GRASS-SHRUB TYPE

The environmental and biological factors that may have limited the invasion of shrubs into desert grasslands before the arrival of European man in North America have to be looked at simultaneously to evaluate the possible role of fire. Vigorous perennial grasses compete strongly with mesquite seedlings (Martin 1975; Wright and others 1976). Experiments on the Santa Rita Experimental Range showed that 16 times as many mesquite seedlings were established on bare areas as in vigorous stands of perennial grasses (Glendening and Paulsen 1955). Wright and others (1976) found similar results in west Texas with no survivors in tobosagrass. Moreover, once established, growth of young mesquite plants is severely restricted in good stands of grass, for the author observed a mesquite plant 12 inches (30 cm) tall in black grama grass that had been planted 18 years before the date that the author saw it on the Santa Rita Experimental Station. Thus, competition is a key factor in keeping shrubs suppressed. Moreover, frequent droughts in the semidesert grass-shrub type (Nelson 1934) were just as hard on young mesquite plants as they were on the grasses (Bogusch 1952).

Droughts can have devastating effects on black grama (*Bouteloua eriopoda*), the most prevalent grass species in the semidesert grassland (Cottle 1931; Nelson 1934). However, black grama can recover quickly following protection and a couple of years of less-than-average to above-average precipitation (Cottle 1931; Nelson 1934; Cable 1975). In 2 years yield increased from 13 to 131 g/m^2 in southwestern Texas (Cottle 1931) and area of sets increased from 3.0 to 78.5 cm/m^2 in southeastern Arizona (Nelson 1934). Regrowth is usually slow the first year of rest but accelerates the second year (Cottle 1931; Nelson 1934). Therefore, when livestock was not a factor, a very susceptible plant such as black grama could have quickly reestablished itself with new stoloniferous plants and have been competitive with shrubs, if it had good vigor at the time of the catastrophy and was followed by average or better than average precipitation (Cottle 1931; Nelson 1934; Cable 1975). During the severe drought of 1951 to 1956, however, nearly all of the black grama on deep sandy and low hummocky sites was lost in an ungrazed exclosure and will not recover in our lifetime under complete protection (Herbel and others 1972). On shallow soils that were underlain by caliche, black grama was much more resistant to the severe drought.

Mesquite seedlings are most prevalent following warm summers and good fall rains (Wright and others 1976). Because grassland fires usually occurred during dry seasons that followed 1 or 2 years of average to above-average precipitation (Wright and Bailey, 1980), a high percentage of young mesquite plants could easily have been killed by fire (Glendening and Paulsen 1955; Wright and others 1976). The few surviving black grama plants (Reynolds and Bohning 1956) on black grama ranges might have recovered quickly, if ungrazed, because they received good summer rains the year before the fire (Cottle 1931; Cable 1975). However, findings by Reynolds and Bohning (1956), where moderate grazing was confounded with fire effects, leave one to doubt whether grazing can be permitted after a burn until black grama is completely recovered. Intervening droughts can lengthen the recovery period for several years (Nelson 1934; Reynolds and Bohning 1956).

For those areas that escaped fire, competition from healthy grass would reduce the number of mesquite plants 94 percent (Martin 1975). Those that survived would be fed on by jackrabbits (*Lepus alleni* and *L. californicus*) (Vorhies and Taylor 1933) and wood rats (*Neotoma* sp.) (Wright and Bailey 1980), especially during dry seasons to meet metabolic moisture needs. In southeastern Arizona velvet mesquite constituted 36 to 56 percent of all food consumed by jackrabbits (Vorhies and Taylor 1933). In well-preserved black grama grasslands, there are relatively small numbers of rodents and lagomorphs (Buffington and Herbel 1965). Thus, competition from grass and feeding by jackrabbits and wood rats appears to have, historically, been major factors that controlled the density and vigor of mesquite in southern desert grasslands.

Frequent droughts, insects, and diseases would also have taken their toll (Bogusch 1952; Glendening and Paulsen 1955; Wright and Bailey 1980). Velvet mesquite seedlings rarely survived the first spring drought on well-grassed sites (Glendening and Paulsen 1955). Those areas that escaped fire for 10 to 20 years could easily have kept young mesquite suppressed (via biotic and nonbiotic factors) to less than 0.5 inch (1.3 cm) in diameter. A fire at this time would kill 52 percent of such trees (Glendening and Paulsen 1955) and probably have kept most of them in a nonseed producing state (Humphrey 1958; Martin 1975). Thus, several factors interacting together with the help of fire and no grazing by domestic livestock could have kept shrubs, particularly mesquite, out of the semidesert grasslands. Even black grama could have theoretically tolerated occasional fires, when grazing was not a factor.

Overgrazing in Arizona, as practiced by forest administrators in the early 1900's to reduce fire hazard and promote the growth of trees (Leopold 1924), helped to prevent fires and let brush encroach upon the grassland (Griffiths 1910). Overgrazing on open range in desert grasslands, particularly during droughts, had a similar effect (Chew and Chew 1965). Griffiths (1910) and Leopold (1924) concluded that before 1880, the southern desert grasslands produced more grass and that fires occurred at approximately

10-year intervals. Initially, fire harmed the grasses, but 10 years was plenty of time for a lusty growth of grass to come back and accumulate the fuel for another fire (Leopold 1924). The poor seed source, slow establishment, and slow growth rate of shrubs and mesquite trees would have permitted a fire every 10 years to control the shrubs and mesquite trees (Griffiths 1910). The key seems to be to burn at frequent enough intervals to prevent the production of seed by the shrubs (Humphrey 1958; Chew and Chew 1965; Martin 1975). No seeds are borne by creosotebush (*Larrea tridentata*) younger than 13 years and significant numbers of fruits appear only after 18 to 20 years of growth (Chew and Chew 1965). With competition from biotic and nonbiotic factors, mesquite could also take this long to have seed (Humphrey 1958; Martin 1975). This reasoning, however, does not seem to apply for southern New Mexico because there is no historical evidence of fire (Buffington and Herbel 1965).

Today, grazing by domestic livestock is the biggest hindrance to the potential use of fire in semidesert grass-shrub vegetation, especially black grama ranges. Grazing has reduced fine fuel for fires and allowed shrubs to invade (Chew and Chew 1965; Martin 1975). Mesquite trees have become well established on former black grama ranges and have further reduced the chance for a site to produce enough fine fuel to carry a fire (Martin 1975). Fire might be used to prevent reinvasion (Martin 1975). In most cases, however, a major reclamation program, involving brush control and improved grazing systems, would be required to reclaim semidesert grass-shrub ranges to grass before fire could be introduced into a management program (Martin 1975; Wright and others 1976).

EFFECTS OF FIRE ON VEGETATION

Grasses

Following a 15-year burning study on the Santa Rita Experimental Range, Cable (1967) concluded that fire had no lasting effects, beneficial or detrimental on perennial grass cover. Generally, the detrimental effects of fire on most of the perennial grasses only lasted 1 to 2 years. Annual grasses (predominantly needle grama and six-weeks threeawn) due to the reduction in burroweed, doubled their yields during wet years (average or above-average precipitation), but remained the same as the control during dry years (below-average precipitation). Humphrey (1949) reported similar results about the response of annual grasses to fire.

Rothrock grama tolerates fire well unless burned during dry years. Reynolds and Bohning (1956) and Cable (1967) found that burning during a dry year caused a 30 percent reduction in rothrock grama. However, it had fully recovered by the end of the second growing season. In an earlier study, Humphrey (1949) found that numbers of rothrock grama plants were more abundant on two different burns near the Santa Rita Experimental Range than on controls 2 years after the burns.

Black grama is harmed most seriously of all the southern desert grasses and is very slow to recover. Following a hot June fire, Cable (1965) found that 90 percent of the black grama plants died. Even during a wet year, black grama only recovered 23 percent of its preburn basal area after the first growing season (Reynolds and Bohning (1956). Following two subsequent drought years and moderate grazing, basal cover of black grama had increased to 33 percent. However, basal area of black grama dropped to 22 percent of the preburn basal area at the end of the fourth year when precipitation was above average. These data indicate that droughts following fire will lengthen the recovery period for black grama (Nelson 1934; Reynolds and Bohning 1956), and if compounded with moderate grazing, black grama will never recover to its preburn basal area (Canfield 1939).

Canfield (1939) found that moderate grazing (simulated by clipping plants to a stubble height of 5 cm) in combination with droughts, regardless of frequency or season of harvesting, reduced the yield of black grama to zero. Moderate grazing entirely outweighed the beneficial effects of above-average rainfall. The result was deterioration of black grama sites through excessive wind and water erosion. Thus, if black grama ranges are burned, they should be completely rested until after two consecutive years of above-average summer precipitation (Nelson 1934; Cable 1975). Then, if grazing is resumed, it should be light.

Rooting of stolons of black grama is the primary method of reproduction. Once these stolons are destroyed, forage is lost and the sand mulch is swept away by winter and spring winds (Herbel and others 1972) unless other grasses can be established on the site. In many cases, other forage does not become established.

Further north near Flagstaff, Arizona, where the precipitation is higher than southern New Mexico, Jameson (1962) noticed only a 25 percent reduction in black grama by prescribed fires. Even hot summer fires did not result in excessive damage. I have observed similar effects in a 15-inch (38-cm) rainfall area in southeastern New Mexico.

Santa Rita threeawn is favored by fire during wet or dry years, but tall threeawns are generally reduced 30 to 50 percent of their original basal cover (Humphrey 1949; Reynolds and Bohning 1956; Cable 1967). During the first growing season after burning, a dry year, Reynolds and Bohning (1956) found that the density of Santa Rita threeawn had increased 34 percent over the control. Following another dry year at the end of the second growing season, the density had doubled. And after the third growing season, a wet year, the density of Santa Rita threeawn had increased 350 percent. Such dramatic increases were not reported by Cable (1967) but it did increase. The reason that Santa Rita threeawn is more tolerant of fire than other threeawns has been explained by Cable (1967). Santa Rita threeawn generally grows in open areas between burroweed plants, whereas the other threeawns generally grow within the burroweed crowns. Thus, the tall threeawns are subjected to more heat and are easily harmed by fire, whereas many Santa Rita threeawn plants are not burned. Generally, threeawn species should be easily harmed by fire because their root-shoot region is close to the soil surface.

Arizona cottontop and tanglehead are mildly harmed by fire during dry years but recover quickly during wet years (Reynolds and Bohning 1956; Cable 1967). Neither of these species shows a gain in production following burning. However, in the southern mixed prairie where the average rainfall is twice as high as in the southern desert grasslands, Arizona cottontop responds very favorably to fire during wet years (Wright 1974). Based on limited data, bush muhly appears to be seriously harmed by fire (Humphrey 1949).

Tobosagrass, a dominant of the southern desert grasslands in southern New Mexico and southeastern Arizona, is severely harmed by burning during dry years (produces only 30 to 60 percent as much as the control), but will recover fully by the end of the third growing season if normal precipitation follows the dry year (Dwyer 1972). In the southern mixed prairie, yield of this species increases twofold to threefold if the soil is moist at the time of burning (Wright 1969; 1972). These differences in response to fire between the two vegetative types can be attributed to differences in precipitation.

Alkali sacaton and sacaton communities, which are similar in density, coarseness, and structure to tobosagrass, were probably burned more frequently in their natural state than tobosagrass communities (Humphrey 1962). Records of fire occurrence are extremely rare. Mesquite and acacia have taken over many sacaton communities. Contributing factors have been overgrazing and channel cutting, which eliminates periodic flooding and lowers the water table. Sacaton grasslands require 2 years to fully regain plant cover and 54 percent of original height (Bock and Bock 1978).

In this community vine-mesquite was significantly more abundant on a winter burned area than on an unburned area (Bock and Bock 1978).

On the northern boundary of the semidesert grass-shrub type, galleta (*Hilaria jamesii*) is slightly harmed by fire (Jameson 1962; Dwyer and Pieper 1967). Following winter burns with adequate soil moisture, galleta yielded 75 percent as much forage the first growing season after burning as the unburned control.

Wolf plants of Lehmann lovegrass, an introduced species, are severely reduced by hot wildfires in June, but seedlings quickly reestablish on the burned areas (Cable 1965). A burn that was followed by unusually favorable moisture for plant growth reduced a stand of Lehmann lovegrass about one-third (Humphrey and Everson 1951). Seedlings were abundant, however, and the reduction in forage yield was only temporary. Following a February burn, Pase (1971) found that lovegrass in a chaparral community was essentially unaffected by burning. Because this species of lovegrass is a bunchgrass, damage by fire would be related to intensity of the fire, amount of dead fuel in plant crowns, soil moisture, and precipitation that followed the burn.

Forbs

Forbs are generally not mentioned in the literature for semidesert grass-shrub communities, but Bock and Bock (1978) reported that forbs which were more common in sacaton communities after winter or summer burning included *Amaranthus, Ipomaea, Bidens, Convolvulus, Solidago, Portulaca, Chenopodium,* and *Ambrosia*.

Cacti

Cactus species are relatively susceptible to fire. Using data from three studies--Humphrey (1949), Reynolds and Bohning (1956), and Cable (1967)--average kills two growing seasons after a burn were jumping cholla, 50 percent; cane cholla, 45 percent; pricklypear, 30 percent; barrel cactus (*Echinocactus wislizenii*), 65 percent. These mortalities usually included the interactive effects between fire, insects, drought, and grazing by rodents, lagomorphs, and domestic animals. For example, when the spines of barrel cactus are burned off, cattle eat them readily (Reynolds and Bohning 1956).

Cane cholla and pricklypear do not recover from the effect of initial burns for at least 13 years after a burn (Cable 1967). However, jumping cholla increased 17 percent 13 years after a burn. Reburns that were 3 years apart did not increase the mortality of cactus species (Cable 1967). The reason given was that the first burn removed the accumulated weeds and litter from the base of cactus plants.

A study by Glendening (1952) also supports the need for fire to control cactus species. His 17-year study showed that cane cholla, pricklypear, and barrel cactus increased under protection and under moderate grazing. Jumping cholla was the only species that decreased under protection. However, jumping cholla has a life span of about 40 years and may go through rapid die-off cycles due to population buildups of bacillus (*Edwinea carnegieana*) (Tschirley and Wagle 1964; Martin and Turner 1977). Die-offs of 25 to 35 percent also occur in the other cactus species from time to time (Humphrey and Everson 1951). To date, there is no evidence to support the common belief that reduced grass competition, resulting from grazing, has caused cactus species to flourish. More likely, lack of fire has caused them to flourish, as the evidence seems to suggest.

Shrubs

Griffiths (1910) and Wooton (1916) believed that fires almost entirely prevented the establishment of undesirable shrubs in the southern desert. Griffiths stated that because of the slow growth of shrubs, he believed they could be controlled by fires that occurred only once in 10 years. Wooton (1916) working in the same area (Santa Rita Experimental Range, Arizona) saw occasional fires that were hot enough to kill mesquite trees 10 to 12 ft (3.0 to 3.7 m) high. In his opinion, fire had been the only restricting influence on the spread of trees and shrubs. Although grasses, with the possible exception of black grama, recovered quickly from such burning, shrubs were usually just reappearing by the time another fire occurred. Regrowth from small mesquites that are merely top-killed can be rapid, however.

One of the most prevalent shrub-tree species in the Southwest is velvet mesquite. This species is moderately affected by fire, depending on the size of mesquite and amount of fine fuel available for burning (Cable 1961, 1965, 1967; White 1969). Following a June 28, 1963, wildfire, Cable (1965) reported a 21 percent kill of mesquite less than 2 inches (5 cm) in diameter and a 10 percent kill of trees larger than 2 inches (5 cm) in diameter. Using artificial fuels for controlled fires, Glendening and Paulsen (1955) obtained a 52 percent kill on young mesquites having basal stem diameters of 0.5 inches (1.3 cm) or less. Only 8 to 18 percent of the larger trees were killed by fire. Reynolds and Bohning (1956) killed 9 percent of the mesquite trees by using a prescribed burn on June 30, 1952. In a wildfire near Sasabe, Arizona, White (1969) reported a 20 percent kill of mesquite trees in moderate and severe burns.

Occasionally, fire may be more damaging to mesquite than is normally expected. Humphrey (1949) has reported mesquite kills of 50 percent on the Beach Ranch Study and 75 percent on the Sierrita Mountain Study. After 15 years, Humphrey revisited these same areas and still found mesquite drastically reduced. High kills such as these reported by Humphrey are rare. Part of this variation in mesquite kills, however, may be due to the amount of fuel available. On areas having 4,500 lb/acre (5 056 kg/ha) of fine fuel, fire killed 25 percent of the mesquites, but on areas having 2,200 lb/acre (2 472 kg/ha) of fine fuel, only 8 percent of the mesquites was killed (Cable 1965). Another source of variation is the general vigor of the plants. Mesquite plants with low vigor, growing on dense rocky subsoils, do not have the recovery potential that more vigorous trees do. Another factor may be the degree to which erosion has removed soil around the base of the tree thereby exposing the bud zone to heat. Lastly, summer burns are more damaging to mesquite than winter burns (Glendening and Paulsen 1955; Blydenstein 1957).

In addition to the mortality of plants, burning seems to inhibit the establishment of mesquite seedlings. Mesquite numbers on an unburned area increased from 16 to 52/acre (40 to 128/ha) within a 13-year period while they only increased from 24 to 25/acre (59 to 62/ha) on a burned area (Cable 1967). Reduced yield of mesquite seed on trees that were partially top-killed may be one reason for such an effect. The reduction in numbers of Merriam kangaroo rats (*Dipodomys merriamai*), resulting from the loss of cactus and other shrubs that formerly sheltered the rats, would also reduce the amount of seed cached on a burned area. Lastly, jackrabbits eat young mesquite plants (Vorhies and Taylor 1933), and the mortality of mesquite seedlings is higher on areas grazed by cattle and jackrabbits than in cattle-jackrabbit exclosures (Glendening 1952).

Generally speaking, velvet mesquite in southeastern Arizona is more susceptible to fire than honey mesquite, which grows in New Mexico and Texas. Two successive fires are necessary to kill 27 percent of the large honey mesquite trees on upland sites in the Rolling Plains of Texas, but trees are rarely killed with successive fires on bottomland sites (Wright and others 1976). Seedlings of honey mesquite are easy to kill with moderate fires until they reach 1.5 years of age, severely harmed at 2.5 years of age, and very tolerant of intense fires after 3.5 years of age (Wright and others 1976). At these young ages, velvet mesquite might be slightly more tolerant of fire

based on data by Cable (1961) but his seedlings had been transplanted when 3 or 4 weeks old. On the High Plains (shortgrass prairie) of Texas, where mesquite was not reported by early scouts, honey mesquite is very tolerant to fire. We have observed no mortality, indicating that the plants have evolved in a fire environment and were kept suppressed by fire, droughts, competition, rodents, and lagomorphs (Wright and other 1976).

Other shrubs, only moderately affected by fire, are false-mesquite (*Calliandra eriophylla*) and velvet-pod mimosa (*Mimosa dysocarpa*). Very few of these plants (2-10 percent) died on severe burns and no plants died on light and moderate burns (White 1969). Reynolds and Bohning (1956) found that false-mesquite recovered within 2 years after burning and had almost doubled its crown density compared to unburned areas by the third year after burning.

Soapweed can be adversely affected by fire. Humphrey (1949) reported a 25 percent kill following a wildfire on Sierrita Mountain. In general, however, most *Yucca* species are tolerant of fires and appear to hold their position in various plant communities despite fire.

Ocotillo (*Fouquieria splendens*) and Wheeler sotol (*Dasylirion wheeleri*) are severely reduced by fire (White 1969). In a June 1963 wildfire many plants of ocotillo died--67 percent in severe burns, 40 percent in moderate burns, and 50 percent in light burns. Only 3 percent of the Wheeler sotol plants survived severe burns, but all survived in moderate and light burns.

Larchleaf goldenweed (*Aplopappus laricifolius*) is also easily killed by fire (White 1969). Severely damaged plants were completely killed and did not sprout by the end of the second growing season. Only 10 percent of the moderately damaged plants survived following fire. About 90 percent of the lightly damaged plants survived in the first growing season, but the number of survivors declined to 80 percent in the second growing season.

Paloverde (*Cercidium floridum*), broom snakeweed, and burroweed are three more species that can be severely damaged by fire. Humphrey (1949) reported a 90 percent mortality of paloverde on the Sierrita Mountain Study. Wooton (1916) observed that broom snakeweed was easily killed by fire. A later study showed that mortalities of broom snakeweed and burroweed following a July control burn were 95 percent or higher (Humphrey and Everson 1951). Cable (1967) and Reynolds and Bohning (1956) have also reported 95 to 100 percent kills for burroweed, when burned in June. One study on burroweed in which burning was done at all seasons of the year showed burning to be reasonably effective from mid-April to mid-September, but most effective about June 1 (Tschirley and Martin 1961).

After 6 years, Cable (1967) found that burroweed was only 25 to 30 percent of preburn density on a June burn (fig. 6), although it fluctuated upward during wet years and downward during dry years. After 4 years, burroweed exceeded preburn densities (fig. 6). However, in another study Humphrey (1949) found that burroweed failed to reinvade after 15 years following a wildfire. The most striking effect of June burns in southern desert grasslands is the elimination of burroweed, at least temporarily, and the increase in annual grasses during wet years (Cable 1967).

Thornber (1907) noted that fire was effective in killing catclaw (*Acacia greggii*), creosotebush, Mormon tea (*Ephedra trifurca*), and graythorn (*Condalia lycioides*). Except for creosotebush, however, no research studies document the extent to which these species are affected by fire. Creosotebush (fig. 7) can resprout after burning, but intense fires, particularly during June, will cause 100 percent mortality (White 1968; White and Ehrenreich 1968).

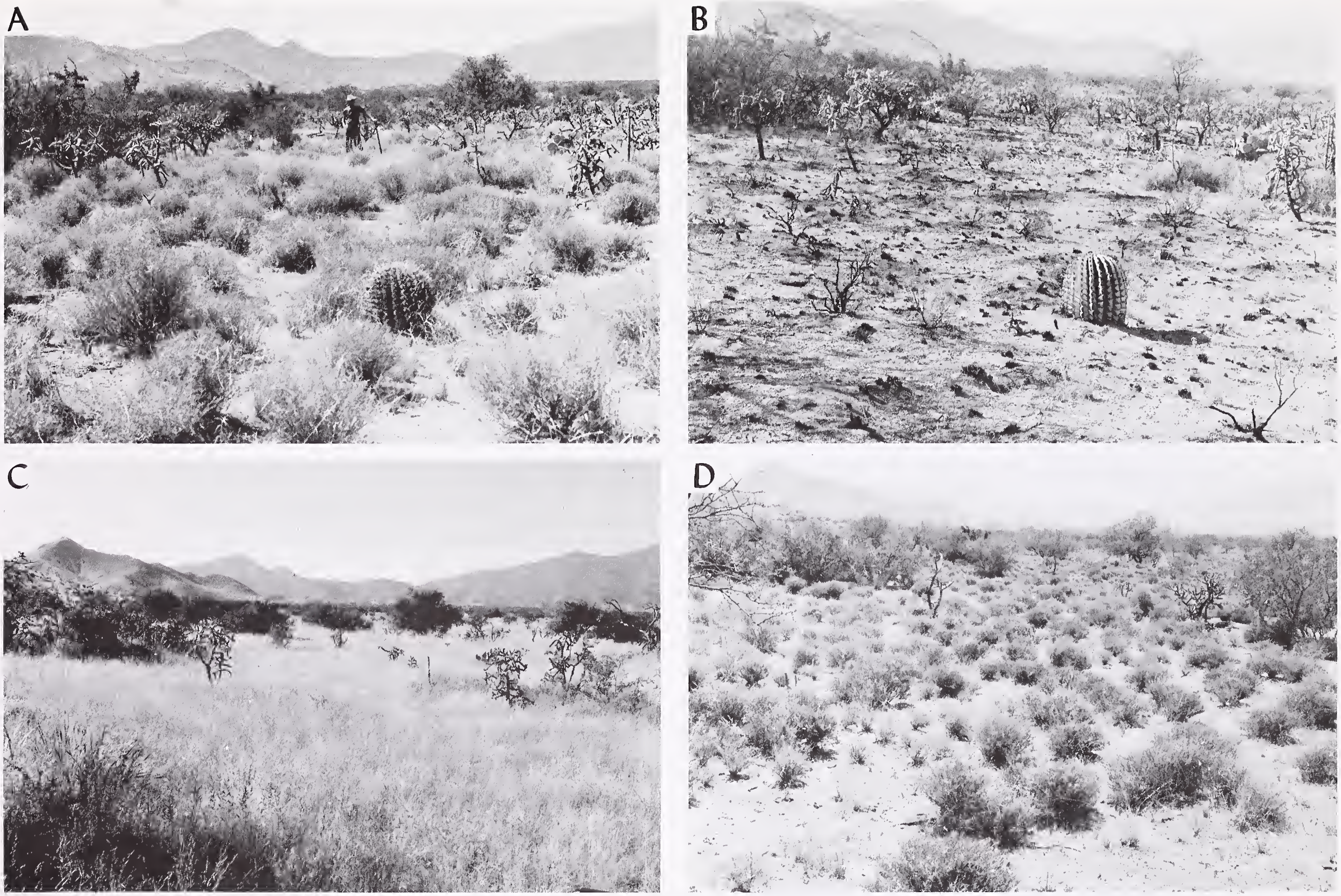

Figure 6.--A. A stand of 4,443 burroweeds per acre on the Santa Rita Experimental Range in June 1952. B. Same as 6A, July 1952, 8 days after burning. Fire killed 94 percent of burroweeds. C. Same as 6A, September 1958. The area is dominated by native perennial grasses. D. Same as 6A, September 1966, 14 years after burning. This site has been reinvaded by burroweed, 10,433 plants per acre.

Figure 7.--Creosotebush is a widespread plant community in the semidesert zone and has very little herbaceous vegetation. However, it is susceptible to fire in June, indicating that wildfires could have easily kept it from invading grasslands in the past.

Algerita (*Berberis trifoliata*), fourwing saltbush, winterfat (*Eurotia lanata*), and skunkbush sumac (*Rhus trilobata*) resprout vigorously after fire (Dwyer and Pieper 1967). Wright baccharis (*Baccharis wrightii*), a highly palatable shrub, also resprouts vigorously and appears to be unaffected by fire (Humphrey 1949).

Desert blackbrush (*Coleogyne ramosissima*) (fig. 8), a nonsprouter in northern Arizona and southern Nevada and Utah (a transitional zone of vegetation between the salt desert shrub and the semidesert grass-shrub types), is very susceptible to fire and is slow to reinvade after fires in southern Nevada and Utah (Jenson and others 1960; Beatley 1966). Plant communities that succeed blackbrush are highly variable (Bowns and West 1976). Bowns and West found that some plant communities will return to a mixture of shrubs such as turpentine bush (*Thamnosma montana*), desert bitterbrush (*Purshia glandulosa*), desert almond (*Prunus fasciculata*), and big sagebrush (*Artemisia tridentata*). Other areas return to pure stands of snakeweed (*Xanthocephalum microcephala*) or big sagebrush. Even though desert blackbrush is not a preferred shrub, widescale burning is not recommended as a desirable management policy for this type (Bowns and West 1976). The vegetation that may follow is too unpredictable.

Figure 8.--Typical view of a pure stand of blackbrush. Note the absence of herbaceous vegetation. (Utah State University photo by James E. Bowns)

PRESCRIPTION GUIDES

Prescription guides have not been developed for the semidesert grass-shrub type. Cable (1967) and Dwyer (1972) have reported the conditions under which they burned. Cable conducted burns on areas with 300 to 600 lb/acre (337 to 786 kg/ha) of fine fuel when air temperature was 77°F (25°C), relative humidity was 15 to 18 percent, and wind was 3 to 6 mi/h (5 to 10 kn/h). In heavier fuel (2,840 to 3,570 lb/acre [3 191 to 4 011 kg/ha]), Dwyer (1972) burned when air temperature was 85° to 96°F (29° to 36°C), relative humidity was 5 to 20 percent, and wind was very slight.

Recommendation: Don't try to burn with less than 600 lb/acre (674 kg/ha) of fine fuel unless a good stand of burroweed is present to help carry the fire. Doze a fireline 10 to 12 ft (3.0 to 3.7 m) wide around the area to be burned. About 600 to 3,000 acres (243 to 1 215 ha) would be a reasonable unit to burn. Strip headfire a 100-ft (30-m) strip on the leeward sides of the planned burning during evening or morning hours in May or June when weather conditions are approximately as follows: air temperature 70°F (21°C), relative humidity 15 to 30 percent, and wind less than 8 mi/h (13 km/h). If the fire continues to back up beyond the 100-ft (30 m) strip, put it out with a pumper. Headfire the remainder of the area when air temperature is 70° to 90°F (21° to 32°C), relative humidity is 10 to 40 percent, and windspeed is 8 to 15 mi/h (13 to 24 km/h).

Quanity of fuel will have a very pronounced effect on fire behavior. Thus, one should do some test burning to approximate the conditions under which fire can be conducted safely and yet accomplish the desired objectives. In heavy fuels such as tobosagrass or sacaton, a backing fire may be adequate to accomplish objectives. However, where fuel is light (less than 1 000 kg/ha), a windspeed in excess of 8 mi/h (13 km/h) will be necessary for the fire to carry through the fine fuel.

MANAGEMENT IMPLICATIONS

The southern desert grass-shrub type is a delicate ecosystem with wide swings in herbage yields because severe droughts are common. Moreover, droughts frequently last 2 or 3 years. When moderate to heavy grazing is superimposed on black grama ranges, grass competition and vigor of grasses are drastically reduced (Canfield 1939). These factors favor high mortality of herbs during drought years and the eventual establishment of shrubs following wet years when other climatic factors, such as soil temperature, are favorable. It appears that use of fire would compound the existing problems on black grama ranges and may not have a place for shrub control on good ranges.

Our problem is to reclaim poor rangelands (predominantly brush), and to properly manage our good rangelands. Poor rangelands cannot be managed with fire. These rangelands must first be restored using other reclamation techniques. However, once the rangelands are in good condition, fire can be used as an effective management tool in special situations during wet weather cycles to control burroweed, broom snakeweed, creosotebush, and young mesquite trees. Fires can also be used to suppress cactus species. Most burning should be done in June, but only following two previous years of better than average plant growth. This is especially important for grasses to recover quickly after burning.

Desirable shrubs that are either favored or not harmed by fire include false-mesquite, velvet-pod mimosa, Wright baccharis, and fourwing saltbush. Wheeler sotol and barrel cactus are easily harmed by fire and should be protected, if possible.

Today, fire should be used only on a selective basis, or in combination with other methods, to achieve specific management objectives in the semidesert grass-shrub type. Fire probably has the greatest value to manage tobosagrass, sacaton, alkali sacaton, and mixed grama ranges. Good black grama grasslands appear to be too delicate to manage with fire. If fire is used, 3 to 4 years rest might be required after the burn.

STATE-OF-THE-ART

Considerable fire research has been done in the semidesert grass-shrub type, but most observations and research have been concentrated in southeastern Arizona. In southern New Mexico, a drier climate, relatively little fire research has been attempted because it was never thought to have played a very important role in the maintenance of southern desert grasslands (Buffington and Herbel 1965). Moreover, now that honey mesquite has invaded many of the sandy sites, fire has no value to restore the sites to black grama grasslands because there is not enough fine fuel to carry a fire.

Since black grama, which is intolerant of fire, was such an important grass in southern desert grasslands over the entire region, long-term research is needed to determine whether fire every 10 years or less frequently could have kept mesquite suppressed. Maybe fire never played a significant role in black grama grasslands, but this question needs to be answered. The following specific questions need to be answered. In what kind of years do mesquite seedlings germinate and become established? How rapidly do these young trees grow under different degrees of grass competition? How easily are trees of specific ages killed? How does the interaction of age of mesquite tree, grass competition, drought, fire, and rabbits affect mesquite growth and seed production?

Cover of black grama fluctuates widely with droughts (Nelson 1934), and most of our fire effects data are confounded with drought and grazing. Fire effects need to be evaluated alone and in combination with drought and grazing. This is important to determine how much fire, drought, and grazing black grama can tolerate. Based on Canfield's (1939) clipping research, light grazing should be the severest grazing treatment that can be used with fire on black grama ranges, if fire can be used at all.

Jackrabbits appear to have been a significant factor in keeping young mesquite trees suppressed in healthy stands of grass (Humphrey 1958). Thus, the preferred dietary balance of jackrabbits and their interaction with other environmental factors in good stands of grass should be carefully studied.

Forb data are minimal in the literature. This is because forbs are insignificant when total herbaceous yield is considered. Because we have to be concerned about the total ecosystem, however, we need better data on forb species to evaluate the impact of our management systems on wildlife. Many wildlife species only need a small amount of specific forb species to exist in certain habitats.

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APPENDIX

SUMMARY OF FIRE EFFECTS DATA BY SPECIES

Table 1.--*Summary of fire effects on major grass species*

Species	Response to fire	Recovery time	Remarks
		Years	
Alkali sacaton) Sacaton)	Tolerant	2-4	Basal area recovers in 2 years, but only 54 percent of height recovers in 2 years.
Annual grasses			
Needle grama) Sixweeks threeawn)	Favored	1	Double their yields the first growing season after burning with average or better than average precipitation. Yields remain the same if precipitation is below average.
Arizona cottontop	Tolerant	1-3	Cover or yields may be reduced 40 percent if precipitation is below average, but recovers the first year if precipitation is average or better.
Black grama	Not tolerant	3-8	Basal area of black grama is reduced 90 percent by hot June fires and remains reduced 78 percent at the end of the first growing season when precipitation is above average. It may need 3 or 4 years rest after a burn before light grazing can be resumed.
Bush muhly	Not tolerant	Unknown	Observations based on very limited data (Humphrey 1949).
Galleta	Tolerant	2	Recovers 75 percent of its original growth the first year after a burn.
Lehmann lovegrass	Tolerant	1-2	Large bunchgrasses can be severely damaged, but seedlings of this species quickly reestablish on the burned area.
Rothrock grama	Favored	1-2	May be reduced as much as 30 percent at the end of the first growing season, but recovers fully with average or better than average summer precipitation.
Tall threeawns	Moderately tolerant	2-3	Original basal cover is generally reduced 30 to 50 percent.
Tanglehead	Tolerant	1-3	Same as for Arizona cottontop.
Tobosagrass	Tolerant	1-3	Yield can be reduced 40 to 70 percent if burned during dry years, but will hold its own if summer precipitation after the burn is average.

Table 2.--*Summary of fire effects on forb and cactus species*

Species	Response to fire	Recovery time	Remarks
		Years	
Forbs			
Amaranthus *Ambrosia* *Chenopodium* *Convolvulus* *Ipomaea* *Portulaca* *Solidago*	Favored	1	Cover of a mixture of these forbs increased 60 percent above the control at the end of the first growing season in southeastern Arizona and remained at this level at the end of the second year after burning.
Cacti			
Barrel cactus	Not tolerant	>15	Reduced 65 percent after burning.
Cane cholla	Moderately tolerant	15	Reduced 45 percent after burning.
Jumping cholla	Moderately tolerant	10	Reduced 50 percent after burning.
Pricklypear	Moderately tolerant	15	Reduced 30 percent after burning.

Table 3.--*Summary of fire effects on shrub species*

Species	Response to fire	Recovery time	Remarks
		Years	
Algerita	Tolerant	10-15	Vigorous sprouter.
Blackbrush	Not tolerant	>28	Nonsprouter. Seedlings reestablish on burned areas very slowly.
Broom snakeweed	Not tolerant	5-10	Ninety-five percent mortality, but reestablishes itself with seedlings following wet winters and springs.
Burroweed	Not tolerant	10-20	Mortality is 95 to 100 percent. After 6 years 25 to 30 percent of the preburn density has recovered. After 13 years, burroweed exceeded preburn densities in one study but had failed to reinvade in another. However, if burns are followed by wet winter-spring periods new stands can become reestablished rather quickly.
Catclaw	Tolerant	10-15	Vigorous sprouter.
Creosotebush	Not tolerant	Unknown	Very susceptible to hot June fires, but some resprouting takes place when burned during other months of the year. A weak sprouter.
False-mesquite	Very tolerant	2	Fully recovers by second year after burning and almost doubles by third year after burning.
Fourwing saltbush	Tolerant	2-3	Vigorous sprouter.
Graythorn	Harmed	Unknown	Can be killed by fire (Thornber 1907), but no research studies have been conducted on this species.
Honey mesquite) Velvet mesquite)	Tolerant	20-30	Young plants are easily killed, but both species are vigorous sprouters. On upland sites two successive burns can kill 27 percent of the large trees, but on bottomland sites mesquite is very tolerant to fire. Large trees of velvet mesquite appear to be more susceptible to fire than honey mesquite.
Mormon tea	Harmed	Unknown	Based on limited observations by Thornber (1907).
Larchleaf goldenweed	Not tolerant	Unknown	Ninety percent of the plants will be killed by hot fires and 20 percent will be killed by light fires.
Ocotillo	Not tolerant	Unknown	Sixty-seven percent died in severe burns, 40 percent in moderate burns, and 50 percent in light burns.
Paloverde	Not tolerant	Unknown	Humphrey (1949) reported a 90 percent mortality following a wildfire.
Skunkbush sumac	Tolerant	10-15	Vigorous sprouter.
Velvet-pod mimosa	Very tolerant	Unknown	Very few plants died on severe burns and no plants died on light and moderate burns.
Wheeler sotol	Not tolerant	Unknown	Ninety-seven percent of the plants died in severe burns, but all plants survived in light and moderate burns.
Winterfat	Tolerant	2-3	Vigorous sprouter.
Wright baccharis	Tolerant	Unknown	Appears to be unaffected by fire (Humphrey 1949).
Yucca	Tolerant	2-5	Very hot fires may cause 25 percent mortality, but generally few plants die following fire.

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Wright, A. Henry
1980. The role and use of fire in the semidesert grass-shrub type. USDA For. Serv. Gen. Tech. Rep. INT-85, 24 p. Intermt. For. and Range Exp. Stn., Ogden, Utah 84401.

Summarizes current knowledge about the effect of fire on vegetation in the semidesert grass-shrub type. Coverage includes, southeastern Arizona, southern New Mexico, and southwestern Texas where grasslands in the southern desert were once prevalent. Sections presented include description of area and vegetation, possible role of fire, fire effects data, prescription guides, state-of-the-art, and management implications.

KEYWORDS: Semidesert; grass-shrub; desert grassland; fire ecology; prescribed burning; fire effects

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The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)